First annual PhD workshop : PhD study of Mechanical Engineering, Naval Architecture and Metallurgical Engineering book of abstracts

University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET

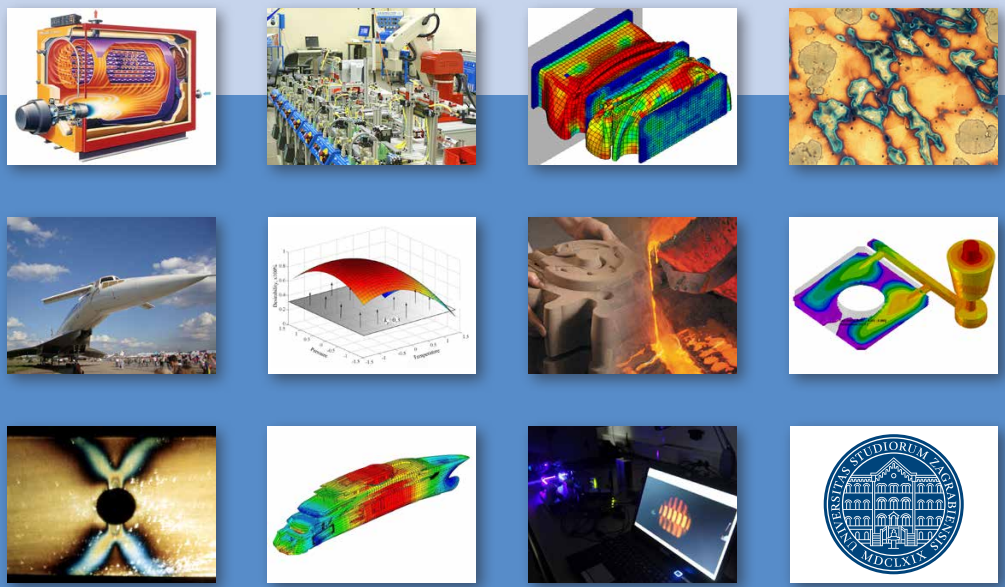
UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

First Annual PhD Workshop

PhD Study of Mechanical Engineering, Naval Architecture,
Aeronautical Engineering and Metallurgical Engineering

Book of Abstracts

July 3, 2015



University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

SVEUČILIŠTE U ZAGREBU
METALURŠKI FAKULTET

UNIVERSITY OF ZAGREB
FACULTY OF METALLURGY

First Annual PhD Workshop

PhD Study of Mechanical Engineering, Naval Architecture, Aeronautical Engineering and Metallurgical Engineering

Book of Abstracts

July 3, 2015

Publishers

Faculty of Mechanical Engineering and Naval Architecture
Faculty of Metallurgy

For publishers

Zvonimir Guzović
Ladislav Lazić

Editors

Joško Parunov
Zdenka Zovko Brodarac
Neven Duić
Dragan Pustaić
Goran Đukić
Franjo Cajner
Biserka Runje
Zdravko Terze
Andrej Jokić
Branko Bauer
Jurica Sorić
Božidar Matijević
Dubravko Majetić

Design and Layout

Mario Lesar
Marko Ban

Printed by

ITG d.o.o., Zagreb

Printed in

70 copies

A CIP catalogue record for this book is available from the
National and University Library in Zagreb under 000909228

ISBN 978-953-7738-34-1

July 3, 2015, Zagreb

Preface

This booklet contains abstracts presented at the First Annual PhD Workshop held at University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, on July 3, 2015. Annual PhD Workshop is the integral part of new PhD programme of Mechanical Engineering, Naval Architecture, Aeronautical Engineering and Metallurgical Engineering, launched on academic year 2014/15. The new program is jointly developed by two faculties of University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy, in order to enhance efficiency of PhD education, to improve scientific excellence of two faculties as well as to facilitate scientific and research cooperation between the academia and the industry.

PhD workshop is aimed to provide forum for exchange of ideas among PhD students, to get all PhD students at one place and to monitor progress of their PhD theses. Workshop should help students to strengthen their presentation skills and unify quality and transparency of PhD theses produced at different modules of PhD programme. Abstract in this booklet are structured in a way to encourage students to write clearly and concisely purposes of their PhD theses in order to bring their research closer to the wide community and even to those who are not specialists in the field. This booklet could be a valuable and relevant reference for PhD students and their mentors as it represents kind of milestone in the progress of their PhDs. It will also be useful for all stakeholders of PhD education to evaluate quality and progress of PhD theses. Finally, it can be useful for the industry in Croatia as it contains in one place most of the research efforts at two faculties.

Contributions collected in the booklet of abstracts are from different modules of new PhD study: Process and Energy Engineering (9 contributions), Theory of Structures (6), Mechatronics and Robotics (4), Naval Architecture and Ocean Engineering (3), Industrial Engineering and Management (3), Scientific Metrology in Mechanical Engineering (1) and Computational Mechanics (1). Diversity of these topics clearly indicates broad and rich research interests and activities at the Faculty of Mechanical Engineering and Naval Architecture and Faculty of Metallurgy. It should be mentioned that presently more than 100 students are enrolled in PhD education at two faculties, but only those among them inscribed in new PhD programme are invited to participate at this First Annual PhD Workshop.

Editors

Contents

Comparison Between ORC Microturbines with Partial Admission

PhD candidate: Mario Klun

Mentor/s: Zvonimir Guzović

Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The utilization of waste heat is one of the important goals of modern process and power plants. These plants use additional cycles with various types of expanders which have been used and tested so far but the presence of turbo machines was almost nonexistent. Just like small steam turbines, the undesired partial admission is present, which changes and complicates the flow.

These turbines use organic fluid as working medium and therefore have slightly different design compared to their vapor running counterparts. The cycle itself is known as an Organic Rankine Cycle – ORC. The motivation for this investigation comes from the fact that no research was performed on ORC microturbines.

Aims

This work aims at researching the physics of flow within the microturbine, and how design parameters (mean turbine blade diameter, rotation speed, stator exit angle, degree of partial admission, blade step and width, and finally the presence of the Curtis stage) influence the flow characteristics.

Methods

Computational Fluid Dynamics – CFD is used to model and simulate the turbine flow. Microsoft Excel and REFPROP are used for turbine –thermo and – aero design, Gambit and MathCAD for flow space/blade modeling, and Ansys Fluent 12.0 for simulating and results postprocessing.

Expected scientific contribution

Overall, the contribution is at the fields of microturbine design (variating the parameters mentioned in the 1st paragraph), applying new technologies (application of 3D printed blade tip flange to avoid tip clearance effects) and use of CFD to calculate and display the turbine flow.

The contribution is displayed as a 3D flow model with all of the parameters of interest (streamlines/vectors of velocity, contours of pressure, temperature, Mach number, turbulence, properties and residuals) as well as undesired phenomena like local supersonic, overall and local swirly flow, as well as difference between calculated and simulated values. In theory, the flow should be smooth without swirl and local vortices but the simulation demonstrates that this is not the case.

Keywords

Organic Rakine Cycle – ORC, Turbomachinery, Microturbine, Partial Admission, Computational Fluid Dynamics – CFD.

Development of Numerical Models Within the Liquid Film and Lagrangian Spray Framework for Application in Internal Combustion Engines

PhD candidate: Jakov Baleta
Mentor/s: Neven Duić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

In IC engines it has been observed that unburned fuel that goes directly into the manifold causes an increase in the emissions of unburned hydrocarbons in the petrol engines and larger product of soot in the compression-ignited engines. Also, injection of precursor substance into exhaust gases before the catalyst leads to the formation of liquid wall film due to unsteady engine working conditions. Above mentioned examples show great importance of the correct prediction of wall film behavior. In order to cope with the present and upcoming emission regulations, automotive industry should develop new, optimized and in every aspect better IC engines. This is possible only by employing advanced designing methods, one of which is CFD.

Aims

The goal of this thesis is further improvement of Eulerian wall film and Lagrangian spray framework by further development, implementation and validation of numerical models, with the final aim of enabling more accurate and computationally efficient CFD calculations of complex physical and chemical phenomena taking part in internal combustion engine. Specific research objectives are implementation and validation of the model for film rupturing, multicomponent evaporation and spray/porous wall interaction.

Methods

This work will try to numerically describe spray and wall film phenomena occurring inside IC engine by further mathematical upgrade of the existing numerical framework which is based on the conservation equations. Within commercial CFD code, based on the control volume approach, developed mathematical models will be implemented using user defined functions in FORTRAN programming language connected with the main solver. After running the test calculations it will be possible to simulate real geometry of IC engine flow domain.

Expected scientific contribution

This research is expected to define models for liquid film rupturing, multicomponent evaporation of the film and interaction of the spray droplets with catalyst structure. The final goal is to develop reliable methodology valid for all relevant phenomena occurring inside catalyst section and inlet manifold that are satisfactory, both qualitatively and quantitatively. The result of PhD thesis is expected to be improved computational tool that will serve engineers for design and optimization of modern IC engines.

Acknowledgments

The candidate wishes to thank AVL List GmbH, Graz, Austria for the financing of the research project and Dr. Milan Vujanović for giving candidate the opportunity to enter the world of real CFD.

Keywords

Computational fluid dynamics, wall film rupturing, selective catalytic reduction, spray/catalyst interaction, multicomponent evaporation

Application of Waste as a Local Energy Source in the District Heating Systems

PhD candidate: Tihomir Tomić
Mentor/s: Daniel R. Schneider
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

In last decades EU is faced with increasing challenges in the energy sector. One of the ways for solving these problems is identification of the potential for the application of high-efficiency cogeneration and district heating which is emphasized in Article 14 of Energy Efficiency Directive. This path includes the usage of local energy sources such as waste and waste materials. Energy recovery of waste is also one of the possible solutions for the problem of waste disposal which is currently a burning issue in Croatia.

Aims

The aim of this study is to model the waste management system (WMS) that could on economically, environmentally and socially acceptable way, solve the problem of waste disposal in the City of Zagreb. Also, this system aims to satisfy part of the city energy needs through energy recovery of the residual waste, which is advocated by the current waste management strategy which envisages the construction of a waste to energy (WtE) plant.

Methods

As a first step, an economic evaluation of constructing a WtE plant is conducted. It is based on regression analysis from data on existing power plants and on the locally dependent data. For this purpose projections of quantity and heating value of waste are conducted. The projections are based on socio-economic data, waste management plans and European legislation. As the next step it is planned to perform an economic optimisation of the size of WtE plant with a heat storage based on local heat demand.

To model a WMS a LCA methodology and the LCA-IWM model is chosen. This model along with environmental sustainability examines economic and social sustainability of the WSM. Necessary input data for this model consist of temporary storage, collection, transport, processing and waste disposal data. By using this model, different waste management scenarios can be compared which can help in determining the best suitable configuration of WMS.

As the WMS is considered as a part of energy system, they need to be modelled as a one integral system. For this task one of the existing energy system models will be used (e.g. EnergyPlan) which will be linked with the WMS model. This way a model of integrated system will be established which will help to keep track of waste and energy flows and will enable evaluation of impact of integration of some other technologies in the existing system(s).

Parallel to this research, development of decision-support optimisation model in WMS is considered which will help determine most acceptable location of WMS components (treatment plant, recycling centre, transfer station, etc.) in urban areas.

Expected scientific contribution

Expected result of this research is to have integrated model that will encompass waste collection, transportation, treatment and disposal as well as the heat demand, production and balancing.

Acknowledgments

The author would like to thank Croatian Science Foundation for providing financial support for this research.

Keywords

waste management system, district heating system, waste model, energy model, model linking

Advanced Planning of Energy Self-Sufficient Wider Urban Areas Using Smart Energy System Approach

PhD candidate: Anamarija Šare
Mentor/s: Goran Krajačić
Affiliation: University of Dubrovnik, Croatia

Introduction

Croatia has issued series of laws and strategies which seek to encourage the use of renewable energy sources (RES) in order to reduce greenhouse gas emissions and to achieve energy system independence. Technologies garnering the most attention are electric vehicles (EV) in the transport systems, the use of RES in the power systems and heating and cooling technologies. The analysis of the power system will be done for the selected Dubrovnik region up to 2050, which has a great potential of RES, including solar, wind and hydro potential, planned to be used in electricity production. Sustainability and flexibility of the system will be ensured trough the integration of smart charging and vehicle to grid possibilities of EV batteries and power to heat and cold technologies that will include appropriate thermal storages.

Aims

The aim is to prove that a 100% renewable power system of a wider Dubrovnik area can be self-sufficient using smart energy system approach. The excess of electricity produced in the system will appear due to the intermittency of RES, which is planned to be stored in EV batteries and thermal storages for heating and cooling demand. High penetration of EVs in the power system will provide the replacement of all conventional vehicles with EVs by 2050. Planned electricity production should meet the needs of the electricity demand in best possible way in order to provide the sustainable system.

Methods

The calculations of the Dubrovnik region energy plan by 2050 will be done using EnergyPLAN model, which is a computer model for Energy Systems Analysis and runs on an hourly basis. It is necessary to collect the data of the current electricity production and demand, RES potential, transport demand and heating and cooling demand. Based on the reference year, further calculations will be done for future scenarios by 2050, including predictions in future electricity production and demand, heating and cooling demand and penetration of EVs in the power system. Optimization of the power system will be provided in EnergyPLAN trough different EV charging models and tariff models on electricity prices.

Expected scientific contribution

The work will provide the improvement of methodology for planning of energy self-sufficient wider urban areas in the context of smart energy systems. Smart approach analyses power system as whole, with all of its aspects at ones, so that the electricity production meets the demand in best possible way, which is the reason why the demand and the production simulations will be given in more detailed way. The borders and constraints for power systems of wider urban areas will be determined. The work will analyse the link between electricity markets and high share of energy production from RES.

Keywords

Energy Planning, Electric Vehicles, Renewable Energy Sources

Windage Losses Sources of the Salient Pole Hydrogenerators

PhD candidate: Siniša Majer
Mentor/s: Željko Tuković
Affiliation: Končar – Electrical engineering institute, Croatia

Introduction

Existing windage losses calculation methods for salient pole hydrogenerators are based on results of applied research, intensively conducted from mid-60s to mid-80s of 20th century. In essence, they are based on the synthesis of theoretical and applied research of resistance of the rotating disk (rotor end faces), rotating cylinder (rotor side faces) and losses generated by active pressure sources in generator (fans, rotor spider, radial ducts in rotor rim, poles). Typically, manufacturers empirically determine dimensionless moment coefficient C_M on the basis of costly model and prototype tests. According to the results of the research conducted by Aljper & Sergievskaja, the range of the moment coefficient for rotor end faces depend on the generator design and its value changes for the whole order of the magnitude. Therefore, windage loss calculation is demanding and it is often the subject of considerable unceartainty.

Aims

The goals of the proposed research are to analyze the most important influential factors on the windage losses, to establish the importance of their interaction, and determine the correlation thus increasing the accuracy of the windage losses calculation. The influence of different shape and arrangement of structural elements will be analyzed and the correlation between these factors and the moment coefficient will be established.

Methods

Research will be based on experimental data collected during extensive ventilation measurements, already conducted on one hydrogenerator. Data from other generators type tests will also be used. On the basis of these data, the CFD model will be validated, and further used for numerical factorial experiments. It is expected that the comprehensive factorial experiments will lead to a more generalised correlations between moment coefficient and a set of the most influential factors on windage losses.

Expected scientific contribution

This research is expected to give new insights on the sources of windage losses:

- To define set of the most significant factors and quantify their relative influence,
- To evaluate and determine the significance of their mutual interactions,
- To establish correlation between set of significant factors and moment coefficient C_M,
- To improve the accuracy and reliability of analytical windage calculations.

Acknowledgments

This research is financed and supported by "KONČAR – Generators and motors Inc." and "KONČAR – Electrical engineering institute Inc." and the results of this research will be used in their in-house calculation tool PROGIP.

Keywords

Hydrogenerator, salient pole, windage losses, CFD, factorial experiments

Influence of Large Scale District Heating Systems on Future Energy Systems and the Role of Heat Demand Mapping

PhD candidate: Tomislav Novosel

Mentor/s: Neven Duić

Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Highly efficient cogeneration and district heating and cooling systems have a significant potential for primary energy savings which are still highly underutilized in the EU. They also represent a very important factor when it comes to the planning of future energy systems because of their potential to increase the flexibility of the overall system and therefore enable a higher level of the utilization of intermittent renewable energy sources like wind and PV. The European Commission recognized the aforementioned advantages, which is made obvious by the Energy Efficiency Directive which clearly states that every member state has to conduct a detailed analysis for the utilization of highly efficient cogeneration and district heating and cooling systems.

Aims

The goal of this work is to develop, present and utilize a heating demand mapping methodology as well the mapping of waste heat sources available for district heating utilization in order to assess the potential for its economic utilization. The obtained data have been used to develop energy scenarios and assess the impact such systems can have on the energy system as a whole, primarily focused on the reduction of the overall energy system cost, the increase of the share of intermittent renewables, security of supply trough the reduction of the utilization of non-renewable fuels and the reduction of CO2 emissions.

Methods

The developed mapping of heating demand methodology demonstrated within this work is mostly focused on publicly available data on building locations and areas as well as some information obtained from district heating operators and city officials. The influence of district heating on the energy system as a whole has been handled through a scenario analysis using the EnergyPLAN modelling tool. Several scenarios have been created and compared in order to achieve this demonstrating individual systems, district heating and power to heat technologies.

Expected scientific contribution

The work will show the potential district heating systems have on the increase in the utilization of renewable energy sources both in the heating and power sectors, increase in the security of supply and reduction of CO2 emissions. Even though similar work has already been done for some EU countries, primarily Denmark and Sweden, Croatia is an interesting case for such an analysis due to its climate and demographic conditions. The results obtained from this work will be utilized in future work to analyse in detail the impact individual aspects such as the distribution of population, locations of potential waste heat and renewable heat sources, climate conditions and the cost of the installation, operation and maintenance of district heating systems have on the optimal share of such systems. The analysis will be universally applicable and demonstrated on several cases.

Acknowledgments

Financial support from the European Union's Intelligent Energy Europe project STRATEGO (grant agreement EE/13/650) is gratefully acknowledged.

Keywords

District heating, Heat demand mapping, Energy planning; EnergyPLAN, Power to heat

Development of a Quasi-Dimensional Combustion Model for the Dual-Fuel (Gas-Diesel) Engine

PhD candidate: Ivan Taritaš
Mentor/s: Darko Kozarac
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

This study presents an initial development of a physically based, quasi-dimensional combustion model for the dual-fuel (gas-diesel) engine. Since the experimental research is both time and financially consuming, and detailed CFD models have high computational time, computationally fast quasi-dimensional models have attracted a lot of attention. Quasi-dimensional models are essentially 0-D models, where the in-cylinder state is calculated only as a function of time. However, contrary to the 0-D models, in quasi-dimensional models, the geometry effects are included in the combustion rate calculation. The development of such model will enable the analysis of in-cylinder phenomena, and assessment and optimization of various engine operating parameters during the engine development stage.

Aims

The objective of this work is the development of a physically based dual-fuel combustion model. In order to achieve this objective, it is necessary to: (1) study the physical processes in the diesel fuel spray; (2) study the physical and chemical processes that affect the diesel fuel ignition delay; (3) study the dual-fuel combustion phases; (4) study the in-cylinder turbulence development; (5) study the multiple flame propagation process; (6) study the start of flame propagation condition.

Methods

In order to achieve the defined objectives of this work, it is necessary to carry out several activities. Hence, this work can be divided into three basic parts. The first part includes the additional literature review on the dual-fuel combustion process. The second part refers to the introduction with the AVL cycle-simulation software, and with the computer programs and program languages, which will be used in the development of the combustion model. The third part deals with the development of the basic structure and various sub-models of the new combustion model.

Expected scientific contribution

The work done within this study presents a huge step in the development of a physically based, quasi-dimensional dual-fuel combustion model. The development and implementation of this model in the AVL cycle-simulation software will enable a better insight in the combustion process and its influencing parameters, as well as faster and cheaper analysis and optimization of various dual fuel engine operating parameters and engine components.

Acknowledgments

This work was done within the FMENA project "Experimentally Supported Development of Advanced Numerical Combustion Models for Internal Combustion Engines", funded by the Croatian Science Foundation and AVL-AST Ltd. company.

Keywords

Internal combustion engine; cycle-simulation; dual-fuel combustion; alternative fuels

Dual Fuel Internal Combustion Engines – Literature Review

PhD candidate: Mario Sremec

Mentor/s: Darko Kozarac

Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Diesel internal combustion engines are the most widely used in transport vehicles. Latest information of world consumption energy shows that the transport is the main source of exhaust gases. Because of environmental concerns, worldwide politics trying decrease amount of harmful gases in earth's atmosphere. To ensure small emissions with acceptable efficiency, automotive industry trying to use alternative fuels, which are more acceptable from environmental point of view. CNG is the cleanest fossil fuel and because of its properties, it can be used in diesel engine with great benefits. Optimal parameters for dual fuel engines are not enough investigated and there is the space for research.

Aims

The most important work on the start of every research project is literature review. The main aim of the literature review is checking results of earlier researches. Through analysing results, the most important thing is to find disadvantages of existing technical solutions and ways for their improvements. In this case, the main aim is to find possibilities to improve emission of HC and CO on low loads with respect to engine efficiency. Furthermore, problems on high loads also must be reviewed.

Methods

Literature review generally consists of studying relevant books of internal combustion engines, books which are related to the specific dual fuel engines and other literature such as articles, conference papers, etc. Besides studying the engine construction, fuels studying are unavoidable. Furthermore, experimental research requires high level of knowledge about engine components, sensors, transducers and other measuring components. The use of appropriate measuring components and understanding conversion of measured signals leads to quality results on the end of experimental process.

Expected scientific contribution

Quality studying of existing dual fuel combustion and its improvement can be relevant for complete automotive industry. The main expected contribution of this research is to find optimal parameters for running dual fuel engine. That means high engine efficiency and minimum of harmful exhaust gasses with maximum of diesel fuel substitute ratio. Most of the time will be spent on research low load operation mode, because in that area dual fuel show some disadvantages. Investigation including experimental setup building in laboratory, so we can expect more researches on that setup in the future.

Acknowledgments

This work is the part of FMENA project "Experimentally supported development of advanced numerical models for internal combustion engines" funded by the Croatian Science Foundation and AVL-AST Ltd. Company. This help is gratefully appreciated.

Keywords

Dual Fuel, CNG Engine, DDF Engine

Working Parameters of the HCCI Engine Propelled with Biogas

PhD candidate: Ante Vučetić

Mentor/s: Zoran Lulić

Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

European Union in 2009 adopted the Directive 2009/28/EC which promotes the usage of energy from renewable sources. Potential solution for reduction of harmful emissions and usage of renewable energy is HCCI (Homogenous Charge Compression Ignition) engine, which has the advantage of lower emissions of nitrogen oxides and particulate matter. Additional benefit of HCCI engine is the ability to work with a variety of fuels, which is particularly interesting in terms of using energy from renewable sources such as biofuels in liquid or gaseous state (biogas). Characteristic of biogas is a high auto-ignition temperature and therefore, in order to achieve stable combustion in the cylinder of the HCCI engine, beside higher compression ratio it is necessary to heat the intake air. Main disadvantage of HCCI engine is difficult control of the combustion start, which is the main reason for the lack of implementation of HCCI engine for commercial purposes.

Aims

By reviewing the literature it can be concluded that the HCCI engine management, especially if it is propelled with biogas, is not a simple task.

Analysis of the combustion process in HCCI engine propelled with biogas and identification of the operating parameters will be performed. This will increase knowledge on biogas, and as a result it is expected for engine to work in a wide range of load and speed. The aim of the research is to determine the influence of certain engine parameters of the combustion process in the case when the engine is propelled with biogas.

Methods

Research will be carried out on experimental single-cylinder HCCI engine which is connected to the engine dynamometer.

Cylinder pressure in correlation with the position of the crankshaft will be acquired using the existing measuring equipment AVL Indismart. Relevant data about pressure and temperature will be acquired with sensors installed on the characteristic parts of the engine, and on the entire experimental setup.

National Instruments equipment will be used for engine management. Data analysis acquired from the experimental setup will be carried out in programs such as NI DIAdem or in self-made software solutions.

Expected scientific contribution

Due to the positive characteristics of HCCI engine in terms of reducing emissions of pollutants, further development of this engine can be considered very useful. If the HCCI engine is propelled with fuels obtained from renewable energy source, such as biogas, the positive impact to environment is even greater.

It is expected to determine the working parameters of the HCCI engine propelled by biogas, and ability for engine to work in wide range of loads, which means larger range of engine applications.

Acknowledgments

This research is partly financed by the project: "Experimentally Supported Development of Advanced Internal Combustion Engine Models" financed by Croatian Science Foundation in cooperation with AVL AST Ltd. Within this project experimental setup of the HC

Keywords

Internal combustion engine, HCCI, biogas, natural gas.

Modelling Innovation as Both a Process and a Product

PhD candidate: Tomislav Martinec
Mentor/s: Dorian Marjanović
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Innovation – a buzzword that already transcended boundaries of business, science and technology. What most researchers agree upon is the importance of organizational innovation, whether for competition and differentiation on their marketplace, sustaining profit, revenues and competitive advantage, and generating more value for the customer and the business. Innovation is recognized to play a central role in creating value and sustaining competitive advantage. In EUROPE 2020 flagship initiative "Innovation Union", it is highlighted that it is more important than ever to deliver the so-called "fifth freedom", which is not only the free movement of R&D resources but also the free movement of innovative ideas.

Aims

The goal of MInMED, a research project in which this PhD research takes part, is to develop a set of fundamental models and methods for innovation management within and across hierarchical social networks exiting in contemporary R&D organizations, and to explore and develop analysis tools in quantifying knowledge and information dynamics as means for prediction of future trends in innovation. Following this goal, the undergoing PhD research aims to model innovation as both a process and a product being developed by individuals, teams and organizations, with focus on information and knowledge exchange between complex engineering systems development stakeholders.

Methods

The integrated analyze – evaluate – create – refine – validate approach will be used as research methodology. As the context of the socio-technological framework requires commitment to methodological pluralism, this research will build on state of the art developments in the exploration of principles of organizational knowledge management and will go further, in that it will seek to incorporate the insights from modelling, simulation and visualization of the complex social, natural and technical systems to the knowledge and information dynamics that encompass the generation, storage, dissemination, filtering, and reprocessing of innovations across hierarchical socio-technological networks.

Expected scientific contribution

The definition of innovation in context of complex engineering systems development will be adapted and a model of innovation as both a process and a product/outcome will be developed. The model will combine different aspects of new product development such as socio-technological networks, sources and diffusion means inside the organizations and from the environment, types of innovation, et al. Corresponding metrics for the measurement of innovation performance will be delivered (including intangible indicators) in order to support comprehensive analyses.

Acknowledgments

This abstract paper reports work funded by Ministry of Science, Education and Sports of the Republic of Croatia, and Croatian Science Foundation MInMED project (www.minmed.org).

Keywords

organizational innovation, product development process, ideation activities

The Evolution of Technical Innovation in Complex Engineering Systems

PhD candidate: Vladimir Smojver
Mentor/s: Mario Štorga
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

The development of new technologies is one of the main driving forces of modern science and industrial growth. Rising awareness of the strategic importance of technology in delivering value and competitive advantage to their respective companies and industrial networks increases the need of accurate predictive models of technology development paths and trajectories. These issues are becoming more critical as the cost, complexity and rate of technology change increases, and competition and sources of technology globalize. Organizations operating in competitive environments demanding process improvements, new product introductions, or technology-enhanced services must obtain and use information on emerging technologies. Therefore, the research on emerging technology and its dynamic development trend is significant in both theoretical and practical ways The purpose of technology forecasting, in this case, is to minimize or eliminate surprise with a listing of potential future events As traditional technology forecasting methods, namely Moor's Law or Kryder's law, have been proved inaccurate a need arises for a new forecasting model which should provide significant insight into technology innovation trajectories.

Aims

The main goal of this thesis is to construct a functioning framework capable of providing forecasts of technology innovation vectors accurate enough to reduce uncertainty. This would be accomplished by developing a number of basic models for managing innovations in a socio-technical context and also exploring and developing tools for quantifying the dynamic of technical innovation and its inclusion in commercial technologies as a means of forecasting future development vectors.

Methods

Traditionally, the method most associated with technology innovation forecasting is the Technology Road Map (TRM) method, a technique widely used within industry to support strategic and long-range planning. Research has been conducted in which a TRM is integrated with knowledge attained by analyzing patent data. Other methods consist of combinatorial models which view innovation as an evolutionary process. Generally, nearly all technology forecasting methods use bibliometrics in order to extract data which is used to extrapolate an innovation trajectory.

Expected scientific contribution

Expected scientific contribution includes a development of new mathematical models for innovation forecasting based on existing models as well as completely new models. Furthermore, a deeper understanding of the transition from idea to technology will be provided as this knowledge is essential to developing accurate mathematical models

Acknowledgments

This abstract paper reports research funded by the Vehicle Center of Croatia and is conducted as part of the Croatian Science Foundation MInMED project (www.minmed.org).

Keywords

Technology management, Technology forecasting, Innovation management, Complex system model-ling

Identification of the Engine Knock Phenomena and EGR Influence on the Combustion Process

PhD candidate: Mladen Božić
Mentor/s: Zoran Lulić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

In order to achieve better brake specific fuel consumption (BSFC) in SI Engines compression ratio is raised, but it is limited with engine knock. Different strategies are used to avoid engine knock phenomena and one of them is application of the exhaust gas recirculation system (EGR). Understanding of the knock phenomena by identification of combustion parameters and characterization of the EGR through experiments represents the motivation for this research. Additional motivation for this study comes from the need for personal and professional development through learning in the field of the internal combustion engine experimental research.

Aims

Up to date understanding of the engine knock phenomena through research of the literature based on the knock indicators and engine parameters. Subsequently experimental setup with the EGR system mounted on the IC Engine is aimed. Through further development of the setup and data acquired influence of the EGR on the increase of engine efficiency will be researched. On the basis of experimental results conclusions that will lead to suggestions for improvement of engine control management are expected.

Methods

As a start of research, deep literature review will be made. After that, research will be continued at the experimental engine setup. For experimental research single-cylinder SI CI Engine coupled with AC Dyno will be used. Furthermore testbed will be upgraded with in-cylinder pressure and engine positioning measurement (AVL Indismart), in-house developed software for regulation of the IC Engine (via National Instruments equipment) and AC Dyno control (via Siemens equipment).

Expected scientific contribution

It is expected that that deeper understanding of the knock phenomena by identification of combustion parameters and characterization of the EGR through experiments will result in scientific contribution of this research. Research of the EGR influence on the IC Engine combustion process gives important development solutions through numerical simulations. These solutions are to be validated through experimental testing on the engine testbed.

Acknowledgments

This work was done within the FMENA project "Experimentally supported development of advanced numerical models for internal combustion engines" funded by the Croatian Science Foundation and AVL-AST Ltd. Company. This help is gratefully appreciated.

Keywords

Experimental setup, Combustion, SI IC Engine, Engine knock, EGR

Propagation of Damage in Ship Structure Caused by Collision or Grounding Accident

PhD candidate: Ivana Gledić
Mentor/s: Joško Parunov
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Ship structural failures may be generally classified as accidental or non-accidental failures. Accidental failures are consequence of marine accidents as collision or grounding. While non-accidental structural failures are the consequence of heavy weather, corrosion, fatigue cracks etc. Usually, accidental failure analysis consists of safety assessment of damaged ship, by assuming that the initial damage, caused by collision or grounding does not change during salvage period. This work aims to extend conventional accidental structural failure analysis by investigating possibility of propagation of initial damage. Damage can propagate across stiffened panels of thin-walled ship structure due to fluctuating wave loading, in a manner similar as large fatigue crack.

Aims

Aim of this work is development of mathematical model that could explain large crack propagation process with reasonable accuracy. Methodology for rapid damage propagation assessment will be proposed, suitable for implementation in procedure for assessment of damaged ship structural safety. The final aim is development of the rational decision making process for damaged ship on her transit voyage from the accident location to the repair facility.

Methods

Crack propagation using fracture mechanics will be used in the proposed research. Both high frequency – low stress fatigue and low frequency – high stress fatigue processes will be studied at the early stage of the research to find out which approach issuitable for this problem. The stress intensity factor (SIF) in stiffened panels of damaged ship structure will be analyzed using one of existing rapid methods for SIF assessment. Candidate methods are the weight function method and the line spring method. Finite element method will be used for calibration of proposed methods. For this purpose, ANSYS software package will be used. Results will be verified by comparison with available experimental results and results of other published calculation models. As damage propagation causes a decrease of hull girder ultimate strength, this new model will be implemented in calculation of residual ship strength during towing period, in order to prevent breaking of the ship in two parts.

Expected scientific contribution

The aim is a development of a new calculation model for rapid assessment of large crack propagation in damaged ship structure. This new model would round up following most important scientific issues: easily calculable stress intensity factor, crack propagation under random loading process and influence of damage propagation on structural safety. This research will make step forward with respect to the present state-of-the-art where only initial structural damage in collision or grounding accident is considered in rational procedures for rescue operation of damaged ship.

Acknowledgments

The research is fully financially supported by Croatian Science Foundation under the project 8658 (Structural Reliability of Damaged Oil Tanker in the Adriatic Sea (DATAS)).

Keywords

Stress intensity factor, crack propagation, damaged ship, collision, grounding

Application of Lean Tools to Increase Efficiency of Product Lifecycle Management

PhD candidate: Tomislav Slavina
Mentor/s: Nedeljko Štefanić
Affiliation: Elektro-kontakt d.d., Croatia

Introduction

Today's advanced production requires from manufacturers to be very innovative, flexible and intuitive in order to keep up with the competition. One of the approaches to reduce defects and improving quality is a lean production philosophy. Lean production philosophy is well known across the globe as a methodology which efficiently reduces waste in the production. PLM was developed as a result of increased informatization of processes. PLM is efficient tool for keep track of product lifetime from its idea, designing, production and maintenance and its recycling or disposal. The benefits of lean production and the PLM system are proven by numerous of scientific researches. Lean production and PLM meet in many of the production aspects and it is only logical to wonder can our production processes by merging the two mentioned tools be improved.

Aims

Some of the scientific studies showed that lean tool can be of use for improving efficiency of PLM, but it hasn't been cleared which of the lean tools are even applicable and which of them are the most useful to combine with PLM in order to improve it. The goal of my paper is to convince people to use lean as a tool for improving efficiency and accuracy of PLM system and to find which of lean methods are the best choice for the benefit of PLM.

Methods

For the purposes of the paper Value Stream Mapping method was used. Value stream mapping is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer. First step was clearly analyzing the current state of the whole process (including the customer and suppliers). Based on that analysis the future state of the process could be created, which, we hoped would bring improvements and eliminate waste. After the future state analysis was done, comparison was made to see what the improvements were. Last step of the method was to work toward the future state condition.

Expected scientific contribution

The first part of the research showed how the use of Value Stream Mapping, as one of lean tools, can make Product Lifecycle Management more efficient, faster, more reliable and more accurate. First, using VSM method, the process efficiency was measured. Then the Kaizen was applied, a lean tool for continuous improvement. The process was measured once again after the implementation of Kaizen, using VSM method. Second part of the research was to establish which of lean tools is most appropriate to use as an improvement tool for PLM. Before implementing the changes, the process efficiency, based to the VSM analysis, was 47.28 %. After the implementation of Kaizen tools process efficiency rose to 91.67 %. From the second part of the research it was concluded that the best lean tools to use for that task are: Just in time, Total Quality Management, Six Sigma, Value Stream Mapping and Kaizen.

Acknowledgments

I would like to thank Professor Štefanić for his expert advice and encouragement troughouth this project. Also, I would like to thank the company in which I work, Elektro-kontakt d.d., for their financial support and other assistance without which this paper would have been impossible to finish.

Keywords

Lean tools, product lifecycle management, PLM, process improvement, value stream map

Novel Meshless Method for Incompressible Flows

PhD candidate: Josip Bašić

Mentor/s: Nastia Degiuli

Affiliation: University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Croatia

Introduction

Mesh-based methods for solving partial differential equations have achieved remarkable success and they are applied in various fields. Creating topologically and geometrically correct mesh is time-consuming work, often with user interventions in mesh generation steps. A simulation with large mesh deformation is difficult to maintain in geometrically complex problems, e.g. fluid-structure interaction. The deformation requires cautious node movement or re-meshing of the deforming area to avoid mesh tangling and its regularity loss. Also, advection errors are much larger compared to Lagrangian methods when fluids with sharp gradients move across cells. Mesh-free methods do not require any connectivity information, thus solving the differential equations in Lagrangian form enables them to naturally simulate advection, large deformations and free-surface, removing the need for mesh generation and deformation management. The most popular method is smoothed-particle hydrodynamics (SPH) which conserves quantities as discretized particles and uses a kernel function to smooth their volumetric contributions. However, SPH methods have number of problems, which require special fixes that sometimes have large cost. In any case, these fixes do not eliminate all low-order inconsistencies. Alternatively matrix and least-squares methods can be used to define consistent, higher-order operators, and renormalization schemes can be used to eliminate the 0-order errors. In this work we analyze a promising new renormalized scheme, for which we introduce Laplacian operator and apply the scheme to solve partial differential equations, i.e. transient incompressible Navier-Stokes equations in strong mesh-free Lagrangian form.

Aims

By investigating mesh-free approximation theory, the first aim of this work was to deduce stable, accurate and computationally efficient spatial operators for the representation of nonlinear partial differential equations. Software was built based on derived conclusions, which implements general solver for the transient incompressible Navier-Stokes equations in two dimensions. The verification and validation of the proposed mesh-free method was done by performing few CFD simulations.

Methods

Numerical mathematical analysis of modern mesh-free approximation theories were researched to find plausible models that can be used to obtain the solution of Navier-Stokes equations. The models were implemented in a software with the C++ programming language, using advanced parallel algorithms suitable for meshless interaction. Incompressible Navier-Stokes equations were solved with the projection method, implicitly using iterative linear solvers. Solutions of some typical CFD tests obtained numerically were compared with known analytical and experimental data.

Expected scientific contribution

In this work mesh-free spatial operators have been proposed, which are minimum second-order accurate and don't require costly numerical operations as other renormalized meshless schemes. In addition to Lagrangian nature of the scheme, the simplicity of the implementation enables the method to efficiently solve the Navier-Stokes equations in mesh-free finite difference or finite volume form. Including the free-surface effects, the introduced method can contribute fluid-structure interaction research.

Acknowledgments

I wish to thank prof. N. Degiuli and prof. Z. Milas for their advices and assistance.

Keywords

meshfree, meshless, computational fluid dynamics, free-surface, fluid-structure interaction

Project Management Model: Integration of Lean Management Tools and Principles

PhD candidate: Goran Kukec
Mentor/s: Nedeljko Štefanić
Affiliation: Zagorje-M.B. d.o.o., Croatia

Introduction

Inspired by everyday work in project management sector as well as design of special constructions in a small company with limits, which are present while using conventional methods, techniques and tools for project management while buyer demands are growing each day there is a need for a new and innovative method. Small and medium-sized companies are presently the biggest employer in Croatia. They are a significant contributor to GDP and are very important part of Croatian economy. On the other hand, regulatory environment in Croatia, incentives and growth of those companies still do not show satisfying level. As there is no possibility to effect on permanent costs growth of fuels, raw material, incremental costs and labour there is a new idea of using the Lean principle and waste identification on a new level.

Aims

Because of local and global survival problem of small and medium-sized companies, new scientific method can give a clear vision, long-term goal and a continuous solution for waste elimination and bigger profitability.

General aim is to explore the possibility if and in which scope Lean tools and principles integration has positive effects on project management and to develop a new method of using the Lean principles on project management. Specific aim is to give an answer if the Lean principle can be used on project management in the company which produces special products by Pull method.

Methods

Analysis of the theoretical knowledge will be done, for in depth understanding of the Lean principles. Research will include Lean principles and its use on the small and medium-sized companies and the use of Lean principles on project management. By synthesis of this research, implementation of the theoretical knowledge in a new method will be done. New method verification will be done on a real case inside the company which produces tailor-made products by Pull method. Comparison of this project will be made with equivalent project, which was managed with conventional methods and techniques. Projects will be analysed according to duration, financial inputs and the amount of the involved entities.

Expected scientific contribution

In depth research of the problems in project management in small and medium-sized companies in Croatia can lead to new scientific cognitions and contributions.

Expected scientific contribution is twofold – theoretical and applied. Theoretical part includes development of the new method based on the Lean principles. Applied part of the contribution is the use of the new method on a real case and the verification and quantification of the method.

Acknowledgments

My gratitude goes to Professor Nedeljko Štefanić for guiding this work and to my work colleagues.

I would also like to extend my deepest gratitude to my family, especially to to my son, daughter and my wife, as well as to my mother and father.</

Keywords

Project management, Lean management, companies, lean inovation

Ship Maneuvering in the Heavy Seas

PhD candidate: Luka Mudronja
Mentor/s: Joško Parunov
Affiliation: University of Split, Faculty of Maritime Studies, Croatia

Introduction

This presentation shows current efforts in ship maneuvering decision making and PhD candidate's efforts for the improvement of the theme. There are two types of approaches for avoiding problems that occur in heavy weather navigation. First is weather routing and means navigation route planning in dependence of the weather forecast. The other approach is applied when the ship is in the storm and seafarers have to make maneuvers to increase safety and reduce wave loads. Candidate's work will deal with second one of described approaches, i.e. maneuvering in heavy seas. Maneuvers that could be done are voluntary speed change and course change. Speed change and/or course change are procedures that are based on seakeeping performance calculations of the ship which are evaluated by seakeeping criteria. Limiting values of the criteria represent border between acceptable and unacceptable seakeeping performances. For seakeeping performance evaluation it is also needed to calculate ship response on sea states. Result of the seakeeping performance calculations are advices for seafarers that show needed maneuvering in the interesting sea states. Noticed problem is impracticality of calculations and results. The possibility of current determination for additional maneuvers will be priceless for seafarers.

Aims

Right and just in time decision making is essential for ship maneuvering in heavy seas. In that way increases ship safety which is main goal of candidate's work. To reach the main goal revision of existing criteria has to be done and development of new approach for determining seakeeping criteria. To reach just in time decision making in navigation, some proposes have to done in field of ship response calculations. First step for improving ship response calculations is cognition from real life situations. The best source of required specific knowledge are seafarers so additional questionnaires among seafarers should provide fundament for validation of the ship response calculations.

Methods

The way to reach main goal leads trough testing different well-known response calculation methods for modern types of ships, revision of existing seakeeping criteria and testing by making questionnaires among seafarers. Revision of seakeeping criteria and their limiting values should be done by iteration among numerical and semi-analytical method and validation with questionnaires among experienced seafarers. Combination of calculated results with fuzzy logic should be fundament for just in time ship maneuvering decision making. Fuzzy values should be derived by Analytic Hierarchy Process (AHP). Fuzzy logic is form of many-valued logic that deals with approximate reasoning. AHP is structured technique for organizing complex decisions based on targets. Targets could be defined such as less slamming, higher speed etc. Performers of the AHP method should be seafarers, also used in the questionnaire.

Expected scientific contribution

Combination of different methods taken from various fields and approaches, such as 3D panel method, AHP method, fuzzy logic, represents innovation in decision making approach for ship maneuvering in heavy seas. Results should be base for future work with final goal of just in time decision making application for enhanced navigation. Revision of existing criteria and development of new seakeeping criteria would help naval architects to make project of the ship with satisfactory seakeeping performances.

Keywords

Seakeeping, ship maneuvering, heavy sea states, de-cision making

Optimization of Lead Time in Make-to-Order Production Through Production Scheduling Algorithms Based on Reduction of MTBO (Mean Time Between Operations)

PhD candidate: Mario Orač
Mentor/s: Nedeljko Štefanić
Affiliation: Končar – Metalne konstrukcije d.d., Croatia

Introduction

Main challenge of make-to-order production environments is lack of standardization and repeatability of products involved, which eventually generates the necessity for flexibility in both capacity allocation and production scheduling. Current production scheduling software and research focuses on allocation of resources and priorities with respect to various generic factors as machine utilization and deadline accountability, but there is a lack of algorithms which are based on optimization of idle time between operations. Therefore, it is necessary to define a new indicator metric for monitoring of scheduling algorithm performance – which is eventually manifested through optimization of both the production lead time and associated costs.

Aims

Primary goal of this research is to create a scheduling algorithm which will be manageable and efficient in make-to-order production environments. Secondary goal is to define a new process indicator for monitoring the performance and efficiency of production processes and associated scheduling algorithm. Eventually, new algorithm and metrics will be implemented in an actual production environment as an integral part of an information system.

Methods

Definition of associated algorithms will be tested in numerical calculations. Various heuristic methods will be tested on scheduling algorithm in aforementioned calculations in order to pick the appropriate one. Chosen algorithm will be programmed within an actual software package and tested live in manufacturing environment in a make-to-order company. Efficiency of scheduling algorithm will be evaluated, among other factors, with respect of previously defined lean metric indicator MTBO (Mean Time Between Operations).

Expected scientific contribution

Lean metric indicator MTBO and its definition will be a completely new scientific contribution and it could be used in various further researches as a mean to test the efficiency of various manufacturing processes. Also, production scheduling algorithm and MTBO based optimization will be a new approach to reduce lead times and associated manufacturing costs in various make-to-order production environments.

Keywords

Production scheduling, make-to-order, lead time, Mean time between operations, lean metrics

Numerical and Experimental Investigations of Wire Crimping Process

PhD candidate: Ante Bubalo
Mentor/s: Zdenko Tonkovic
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Yazaki is one of the leading companies in field of connector and wire harness production. When designing new product it is important to validate product features before production. Terminal design is very complex, because there are a lot of demands by customers. One of the demands is regarding crimping, where customers request to crimp two sizes of the wires on one size of a terminal. Difference in area of those two wires is up to two times. If terminal wings are not optimized well, crimp will fail on validation test. When I started working on this crimp issues, I realized that there is a lot of place for research and it was my motivation.

Aims

Research will be based on metal forming issues, and wire crimping model will be made to prove hypothesis of work. The modelling of such problems using the finite element (FE) method is a challenging and complicated task. The nonlinear dynamic models include complex constitutive equations, nonlinear kinematics, friction and large contact pressures, which lead to element overclosure and non-physical behaviour of the model. In metal forming it is crucial to define spring back with proper constitutive model.

Methods

Wire crimping process will be investigated both numerically and experimentally. Within the framework of numerical investigations the three-dimensional simulations are performed using implicit and explicit finite element methods in the FE program ABAQUS/Standard and ABAQUS/Explicit. The results from an implicit modelling approach are compared to those obtained from an explicit dynamics formulation. In addition, computational procedure accuracy is verified by comparing the computed results with the real experimental data.

Expected scientific contribution

These crimping simulation results will determine if explicit or implicit formulation is more suitable for metal forming process. Herein, parametric studies are performed to show the effect of the different contact formulations and friction conditions on the numerical results. Influence of different constitutive models (user subroutine – VUMAT) will be determined.

Acknowledgments

This work has been supported by the company Yazaki Europe LTD. With special thanks to Mr. Ranko Resman, Mr. Volker Hinne and Mr. Thomas Schaller.

Keywords

wire crimping, metal forming, explicit

Advanced Model for Long-Term Energy Planning with Application of Multi-Criterial and Multi-Level Optimization on a Multi-Processor Architecture

PhD candidate: Goran Gašparović
Mentor/s: Goran Krajačić
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

Sustainable development demands a sustainable energy system. Fossil fuels can not be the only energy source choice in a future dominated by renewable energy sources (RES). It is necessary to technologically upgrade the existing energy system with improved methods of energy planning, implementation of smart grids and integration of RES production. For 100% RES system, there is a need for techno-financial optimization to formulate a proper understanding of the problem. Development of the mathematical model and use of optimization brings optimal conditions of use for complex energy systems, with savings in investment, maintenance and operation and greenhouse gasses (GHG) reduction in emissions.

Aims

The aim of the work is to present the efficiency of optimization and multi-processor computation for individual components of an energy system, and optimal dimensioning and scheduling compared to the existing approach of aggregating components. Basic concept describes the interaction of RES intermittency with compensation in production and meeting the demand through the use of energy storage. Problems to be modelled and explored are strategies of phase-in and phase-out of generating and storage capacities. Prior to the verification of simulations of an energy system, a mathematical model needs to be developed with all the components, economical model, adaptation of exisiting or development of new optimization algorithms and coding of software for multi-processor calculation.

Methods

Methodology is based on numerical methods. Basic concept is balancing the energy system by optimizing the most expensive component of the system, energy storage. Two levels of optimization are employed, primary for determining the capacity of the system, and secondary for planning the utilization of the components. Multi-target optimization includes dimensions for minimal installed power, minimum emission of GHG or minimum levelised cost of energy (LCoE).

Expected scientific contribution

The outcome of the work should conclude with a mathematical model capable of optimizing energy systems with high share of RES and energy storages from micro grids to continental-level size with individual component modelling. Economical model for Multi-year calculation for phase-in, phase-out and operation and maintenance will be presented. Strategies for daily, weekly, monthly, seasonal and yearly utilization of storages will be developed and tested.

Acknowledgments

The author would like to thank Croatian National Science Foundation project MICROGRID (08/40) (2012-03/2015-03) and IEE project BEAST (2015-03/today) for the funding.

Keywords

Long-term energy planning, multi-objective optimization, multi-level optimization, multi-processor computation, renewable energy sources

Oil Refinery Efficiency Improvement Through Integration of Renewable Energy Sources

PhD candidate: Almir Sedić
Mentor/s: Zvonimir Guzović
Affiliation: INA – Industrija nafte d.d., Zagreb, Croatia

Introduction

Expectations that oil refineries will be shut down in near future are not realistic, because oil is still essential for strategic industries such as transport, aerospace sector and military. Additionally, consumers are not yet ready to forfeit distinct advantages of fossil fuels, i.e. their availability and planning options. Considering also EU directives regarding CO_2 emissions and simultaneous increase of renewable energy sources share, a reasonable conclusion would be that energy management in refineries has to be significantly changed over a short time period. This is an especially daunting task in the case of primary oil processing plants, because these are the largest energy consumers in refineries, while also being the most rigid energy consumption-wise due to process physical restrictions.

Aims

This work aims to analyze an actual oil refinery energy system constructed 25 years ago, with the scope of efficiency increase, own consumption and CO_2 emissions reduction, and improving energy system adoption possibilities in variable production regimes environment. Accordingly, new energy sources will be proposed and special attention is going to be given to opportunities for implementation of alternative energy sources as the main tool for achieving defined goals. Results of this work will be used for the development of general plant model aimed at efficiency improvement and CO_2 emissions decrease through integration of renewable sources in refineries.

Methods

The key prerequisite for production and efficiency analysis is data collection during different production cycles and operating regimes. The analysis tools applied should include established methodologies for efficiency improvement and process integration, and result in final definition of plant energy system design. In particular, renewable energy sources, as well as heat and electrical power storages, should be adjusted and integrated within energy system in accordance with specified energy consumption and CO_2 reduction targets. Changes of actual process unit's energy parameters are not considered. Instead, analysis results will be used to propose optimal parameters within the upgraded part of the energy system.

Expected scientific contribution

The expected scientific contribution is a general model of integration of renewable energy sources within the complex oil refining production system for efficiency improvement and CO_2 emissions reduction. The plant model is going to include specific energy system features, such as implementation of intermittent energy sources within such a highly-dynamic energy system characterized by abrupt process parameters variations, and restricted ability for alteration of energy consumption for major consumers, while also satisfying variable energy consumption of process plants.

Acknowledgments

It is gratefully acknowledged that this work has been supported by INA – Industrija nafte, d.d., Zagreb, Croatia.

Keywords

renewable energy sources, energy efficiency increase, CO_2 emissions reduction, highly-dynamic energy system, oil refinery

The Potential of District Heating and Cooling in Croatia in Terms of High Energy Efficiency and Maximum Integration of Renewable Energy Sources

PhD candidate: Danica Maljković
Mentor/s: Neven Duić
Affiliation: Energy Institute Hrvoje Požar, Croatia

Introduction

Energy consumption in households in Croatia on an annual basis makes about 74 PJ (services 30 PJ). If it is known that about 75% of energy consumption in households makes energy for heating and domestic hot water, and about 40% of the energy in the service sector is used for the same purpose, it can be said that of the total energy consumed in Croatia on an annual the level of just under 18% is spent on space heating and domestic hot water. Of the total consumption in households for heating and hot water in Croatia about 20% is produced in the public cogeneration plants and public heating by thermal energy supplied to consumers via remote district heating systems. The potential for larger implementation of district heating and cooling systems in considered to be significant.

Aims

The aim is to define the baseline status of Croatian district heating systems, and overall thermal energy needs, both heating and cooling, of Croatian households and industry. After defining the overall potential for maximum integration of district heating and cooling (DHC) different scenarios will be defined with DHC as energy storages used to maximize renewable energy penetration in Croatian energy system. Direct hypothesis is that the maximization of DHC will assure at least a 50% renewable energy (RES) and 100% zero-CO2 integration in Croatia by 2030.

Methods

A comprehensive research of energy consumption Croatian household's consumption has been performed with personal on-field interviews in 5.000 household, the number considered to be an appropriate statistical sample. This research has been performed for the first time and is giving very reliable, while all of the previous researches where based on the number of energy consumption assumptions. Household energy consumption is them modelled in the "EIHP model", an energy consumption model developed in Energy Institute Hrvoje Požar" that is developed based on the "End-use" approach, and that categorizes the overall consumption into different consumption categories. In this paper comparison of "EIHP model" with a number of other models will be made and the most suitable model for Croatia will be identified. "EIHP model" capture the impact of all relevant terms of energy consumption as well as the growth and structure of domestic product, demographic changes, housing standard, population mobility, climate, changes in efficiency of energy use, habits, customs and the like.

Expected scientific contribution

The most suitable energy model will be identified for the Croatian energy system, and calibration of the methods used in other countries will be performed. Based on the best model identified by comparison of a number models the most suitable model for Croatia, as a Mediterranean country with regions with continental climate will be defined, and will be used to calculate the maximum RES and cogeneration penetration possible with DHC systems used as energy storages. Methodology that will be used will be adapted to the markets that have a price distortion, low level of energy efficiency and can further be used in other such markets.

Acknowledgments

To Energy Institute Hrvoje Požar for providing the household energy consumption interviews results.

Keywords

District heating, district cooling, energy efficiency, renewable energy integration

Dynamics and Control of Unmanned Aerial Vehicles (UAV) with Vertical Take-Off and Landing (VTOL)

PhD candidate: Matija Krznar
Mentor/s: Danijel Pavković
Affiliation: Peti Brod Ltd., Croatia

Introduction

In modern times there is a growing interest in scientific research of Unmanned Aerial Vehicles (UAV). The object of this scientific research is a four-propeller helicopter (so-called quadrotor, or quadcopter). The aircraft of this type is characterized by unstable multivariable coupled dynamics, six degrees of freedom (6DOF), and under-actuated control action due to limited number of propulsion actuators. For such an aircraft to be properly stabilized and controlled, there is a need for the implementation of advanced control and estimation algorithms.

Aims

The first stage of this research aims to develop a system of Proportional-Derivative-Integral (PID) controllers for quadrotor altitude, attitude and heading within a Matlab/Simulink simulation environment. Further step in research is development of expanded model with a full inertial sensor complement, along with a sensor fusion system that will include adaptive signal filtering required for the suppression of measurement noise effects. Measurements from all external sensors will be analyzed in time and frequency domain in order to determine their dynamic and quasi-steady state features (bandwidth, signal-to-noise ratio, offset and drift), along with possible sources of signal distortion. Moreover, a detailed model of the propulsion system with included motor and propeller friction, inertia and aerodynamic effects will be implemented within the simulation environment, in order to study their influence to the quality of the propeller-based actuation system response and overall aircraft dynamics.

Methods

Mathematical model of quadrotor is derived from the three-axis rotational and translational dynamics of a rigid body system, and implemented within a computer simulation environment such as Matlab/Simulink (or Scilab/Xcos), and Python open-source software development environment. The purpose of cross-platform software implementation is for experimental verification and interpretation of results. The obtained simulation results will be verified on the experimental setup featuring a hardware-in-the-loop (HIL) system suitable for half-aircraft dynamics emulation. After successful tests of HIL system, a full experimental model of quadrotor will be designed and constructed for control system testing purposes.

Expected scientific contribution

It is anticipated that valuable scientific contributions in the field of energy management and optimization can be obtained through research of quadrotor energy requirements and related flight control system design based on suitable optimization criteria combining flight time duration and actuator response speed indices, such as for aggressive maneuvering and level flight stability with respect to disturbances (wind gusts). Moreover, research efforts in the fields of quadrotor servo propulsor optimization and control, Brushless DC motors (BLDC) speed sensing, on-board battery State of Charge (SoC) and State of Health (SoH) estimation and Kalman filtering-based sensor fusion also show significant potentials for scientific contributions.

Keywords

Quadrotor control , modeling of the propulsion system with included motor and propeller friction, battery management, sensor fusion

Control of Spatially Distributed Dynamical Systems

PhD candidate: Mihael Lobrović
Mentor/s: Andrej Jokić
Affiliation: Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia

Introduction

Spatially distributed dynamical systems are composed of a large number of dynamical subsystems which operate under constant mutual interactions through some physical interconnections and/or communication links. Today, it is widely recognized that the key challenge in development of efficiently operating spatially distributed dynamical systems is synthesis of algorithms for their control. Although we are capable to develop reliable subsystems and shape their local behavior, we still miss complete and practically applicable theory which would give us firm answer to the question of what the global behavior of the overall dynamical network will be when all the subsystems are interconnected.

Aims

The ultimate aim in this research is to design local controllers and the scalable algorithms for their coordination so that the dynamics of local systems in the dynamical network is shaped in such a way that some predefined global objectives and constraints are met. In order to enable efficient operation of the controlled dynamical network, it is also of crucial importance that mathematically formulated stability and performance are not too conservative.

Methods

The methodology is based on dissipativity theory and innovative employment of dynamic supply rates. By systematic modelling of uncertainties and by taking them into account during the controller synthesis process, robust control solutions will be obtained. Recent results which show certain equivalence between linear parameter varying control synthesis problems and distributed control synthesis problems will be also exploited. Proposed control algorithms will be experimentally verified on the group of mobile robots and on a series of three inverted pendulums interconnected by springs.

Expected scientific contribution

Understanding of how robustness emerges in complex dynamical networks, and development of suitable mathematical tools and algorithmic procedures to enhance both robustness and efficiency while being aware of the fundamental limitations and trade-offs in design of any complex system will have direct impact in many areas: biology, economy, engineering. The step in direction of answers to this questions will make a contribution to interdisciplinary knowledge and science in general.

Acknowledgments

This research is fully supported by Croatian Science Foundation under the project 9354 Control of Spatially Distributed Dynamical Systems.

Keywords

distributed control, dissipativity, LPV control

Development of New Loading System for National Force Standard with Nominal Value of 1000 N

PhD candidate: Mia Videc
Mentor/s: Željko Alar
Affiliation: Mosaic Solutions, Croatia

Introduction

Force is one of the most important physical quantity for defining different mechanical properties as well as for designing and dimensioning in engineering. It can be directly defined from three elementary physical quantities – mass, length and time and its unit can be directly derived from three elementary SI units – kilogram, meter and second. While working in HMI/FSB-LIMS for five years in the field of force measurements and calibration, many contacts and cooperation with different national force laboratories were achieved. From that an idea for developing deadweight force calibration machine was born.

Aims

The aim of this research is to design and manufacture a machine with direct force realization by weights (masses) in Earth's gravitational field, both for tension and compression. The machine should comply with current international standards and have excellent measurement capability. To achieve that it is necessary to make weights with optimal combination of properties, to improve current mechanisms of force transfer and to minimize the influence of different measurement uncertainties.

Methods

Methods used in the research will be theoretical, experimental, mathematical and statistical. Theoretical phase is elaboration and valorization of the design of the machine as well as selection of material and technology for weight manufacturing. Experimental phase is testing of weights' material properties, machine manufacturing and estimation of some of the uncertainty influences. Mathematical and statistical methods include estimation of expanded measurement uncertainty and calibration and measurement capability (CMC) through direct calculations as well as interlaboratory comparisons.

Expected scientific contribution

This deadweight machine should enable the expansion of current measuring range in calibration of force-proving instruments towards lower forces and it should potentiate improvements in the field of hardness calibrations. Also, powder metallurgy of stainless steel is to be explored as a potential technology for manufacturing weights with optimal combination of properties, while improvements in force transfer could decrease some uncertainty influences.

Acknowledgments

I would like to thank to all of my ex-colleagues from HMI/FSB-LIMS and especially to Željko Alar, Ph.D. as a mentor for this research.

Keywords

force, mass, deadweight, measurement uncertainty

Optimization of Automatic Transmission Shift Control – Abstract

PhD candidate: Vanja Ranogajec
Mentor/s: Josko Deur
Affiliation: University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia

Introduction

There is a strong tendency of increasing the number of gears of planetary gear automatic transmissions (AT) in order to improve the powertrain efficiency. The number of clutches increases, as well, where one of design goals is to have as many locked clutches as possible in order to reduce the drag losses. The shift control for such advanced ATs becomes more complex and in order to gain an insight into optimal control strategies and performance it is necessary to have a mathematical model of the observed AT. For specific AT analysis, the AT model order can conveniently be reduced by eliminating the state variables related to locked clutches. So far, research activities were focused on modeling and model-order reduction methods.

Aims

A complex system such as AT transmission is modeled using bond graph (BG) modeling methods. One of the goals is the development of AT simulation model using BG modeling methodology which is capable of quantitatively analysing and predicting AT dynamic characteristics. Starting from the full order BG model of AT and with given clutch application state vector, the system matrices of reduced order can be obtained. Different approaches and methods will be discussed for this purpose.

Methods

The 20-Sim software package is used to create a bond graph model (BGM) of the AT and transform it into the full-order state-space mathematical model. The same software is used with the aim of obtaining the reduced-order model. A MATLAB has been used for automatic communication with 20-sim.

Expected scientific contribution

The development of new methods and tools for the automatic modeling of complex automatic transmission models is expected. A fully-automated model-order reduction method development is planned in the future work which also include the corresponding software tool for an arbitrary AT system. Resulting reduced-model system matrices can be used for different applications such as analysis of system behaviour, shift control optimization or control strategy development.

Acknowledgments

It is gratefully acknowledged that the work has been supported by the Croatian Science Foundation. The research results were achieved within the Ford URP Project "Optimization of Automatic Transmission Shift Control".

Keywords

automatic transmission, modeling, simulation, model-order reduction

Autonomous Mobile Robots in Industrial Environments

PhD candidate: Tomislav Pavlic
Mentor/s: Mladen Crneković
Affiliation: Technical College in Bjelovar, Croatia

Introduction

The eMIR robot (educational Mobile Intelligent Robot) was developed at the Chair of Engineering Automation at the Faculty of Mechanical Engineering and Naval Architecture in Zagreb. An experimental test site 4x2m in size, previously unknown to the robot, is used as a replacement of a manufacturing facility site 40x20m in size. The guiding principle of the research is autonomous behaviour of a mobile robot at a test site. Mobile forklifts (in this case, eMIR robots) autonomously perform load manipulation. In this research, multiple robots participate in a mutually coordinated activity, whereby their productivity increases. It is necessary to develop algorithms that will enable eMIR robots quality autonomous docking to a charging station. In the remainder of the research, efforts will be directed towards improving the behaviour or mobile robots in unpredictable non-static environments that constantly and dynamically change.

Aims

Expected research results include the following:

- Finding a simpler solution to solving the problem of 24-hour autonomous robotic activity (exploring a simpler approach to docking a robot to a charging station
- Exploring the possibilities of the Python open-source programming environment regarding application for the eMIR robot
- Developing a functional platform for examining algorithms for guiding mobile robots
- Exploring the possibilities of independently including eMIR's visual system algorithms into the robot's control algorithms

Methods

The majority of today's programming languages used for mobile robots are oriented towards the kinematics of robotic motion (position, speed, angle, orientation), i.e. towards explicitly setting the motion of a robot, but not the task to be performed. In this way it is possible to solve a limited set of problems, primarily regarding highly predictable environments. All recognition and control algorithms were tested on an eMIR mobile robot and at an appropriate test site. In order to make a mobile robot behave intelligently (autonomously, in an unpredictable environment), at least three problems have to be tackled with: 1. survey of space, with the purpose of creating its model, i.e. the SLAM (Simultaneous Localization and Mapping) problem; 2. planning the trajectory of a robot in the spatial model (full or partial, static or dynamic); 3. realisation of the planned trajectory in real space.

Expected scientific contribution

- Developing eMIR's control algorithms for visual recognition of static and dynamic obstacles in an unpredictable environment
- Including eMIR's visual system algorithms into its control algorithms, therefore making possible autonomous robotic behaviour (movement, localisation, battery recharge) in an unpredictable environment
- Developing and testing eMIR's task-oriented control algorithms (as opposed to motion-oriented ones)

Acknowledgments

Whole work that has been done is thanks to joint efforts of Tomislav Pavlic MSc Mech Eng, Prof Mladen Crneković PhD, and Marin Lukas BSc Mech.

Keywords

eMIR mobile robots, autonomy

ISBN 978-953-7738-34-1